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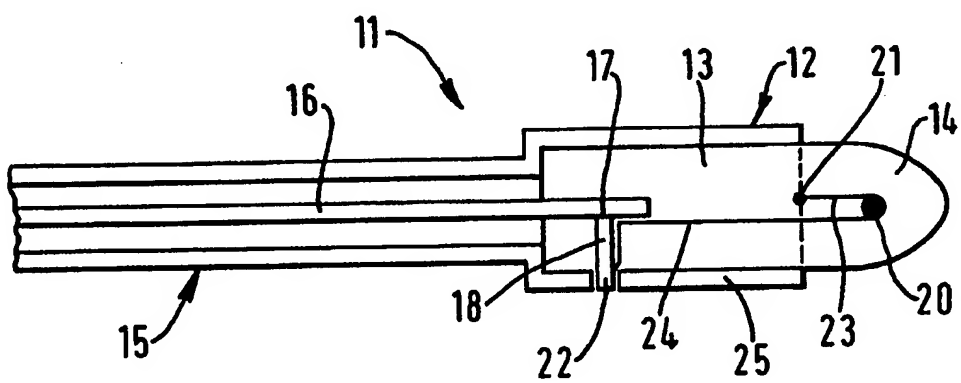
(54) Title: THERMAL SENSOR POSITIONING IN A MICROWAVE WAVEGUIDE



(57) Abstract

A method of positioning on a microwave waveguide a sensor (20) including an elongate metallic element (23, 24) comprising: selecting a tubular waveguide (12); determining the general orientation of the magnetic field (3) generated during microwave transmission; and positioning the elongate metallic element (20, 23, 24) substantially parallel to the orientation of the magnetic field (3). Connections (23, 24) of the sensor (20) extend longitudinally of the waveguide (12) and are connected to the outer wall (25) of the waveguide and the central conductor (16) of the coaxial cable (15) that powers the waveguide.

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THERMAL SENSOR POSITIONING IN A MICROWAVE WAVEGUIDE

Technical Field

This invention relates to positioning a sensor on a microwave device, especially an applicator for treatment of a body by means of microwave electromagnetic energy, and also relates to an applicator including a sensor positioned thereon.

In our prior published application No. WO95/04385, the contents of which are incorporated herein by reference, we have disclosed apparatus for the treatment of menorrhagia which involves applying microwave electromagnetic energy at a frequency which will be substantially completely absorbed by the endometrium, monitoring the operating temperature to ensure that the endometrium tissue is heated to about 60° and maintaining the application of the microwave energy for a period of time sufficient to destroy the cells of the endometrium.

The temperature is therefore important and a temperature sensor in the form of a thermocouple is used to monitor the temperature on an ongoing basis during application.

The problem which arises is that a thermocouple is constructed of metal and the application of microwave energy tends to cause direct heating of the thermocouple which leads to errors in the temperature readings. This general problem is discussed in S.B. Field and J.W. Hand "An Introduction to the Practical Aspects of Clinical Hyperthermia" at pages 459-465. As a result of the problems encountered with metallic sensors, it has been the

practice to take readings either when the power is off, which precludes real-time measurement, or measurement has been by non-metallic sensors, such as fibre-optic sensors, which are much more expensive.

Microwave electromagnetic energy can be propagated either by coaxial waveguide or by tubular waveguide typically of circular cross-section.

Disclosure of the Invention

The invention consists in a method of positioning on a microwave waveguide a sensor including an elongate metallic element comprising: selecting a tubular waveguide; determining the general orientation of the magnetic field generated during microwave transmission; and positioning the elongate metallic element substantially parallel to the orientation of the magnetic field.

With this arrangement, current should not be induced in the metallic element by the magnetic field and there should therefore be little or no interference with the parameter being sensed. Typically, the sensor will be a thermocouple sensing temperature and the inherent danger is interference by current flowing in the metal sheath of the thermocouple.

The invention also consists in a microwave applicator comprising a tubular waveguide which, on transmission of microwaves, generates an electric field orientated substantially perpendicular to the waveguide wall and a magnetic field substantially perpendicular to the electric field, and a sensor including an elongate metallic element, said elongate metallic

element being positioned on the waveguide so as to extend substantially parallel to the magnetic field during microwave transmission, whereby substantially no current is induced in the metallic element of the sensor which would otherwise cause distortion.

Description of the Drawings

The invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a diagrammatic side elevation of a coaxial waveguide according to the invention showing the electric and magnetic fields;

Figure 2 is a diagrammatic cross-section of the waveguide of Figure 1;

Figure 3 is a diagrammatic plan view of the waveguide of Figure 1;

Figure 4 is a perspective view of the waveguide of Figure 1; and

Figure 5 is a diagrammatic side elevation of a microwave applicator according to the invention.

In Figure 1, the diagrammatic cross-section of a coaxial waveguide is shown where (1) is the centre conductor and (2) is the outer conductor. When propagating microwave energy in a coaxial waveguide both the magnetic field (3) and the electric field (4) are always perpendicular to the axis (the centre conductor). Since currents (5) always flow at right angles to the magnetic field they will always flow along the coaxial waveguide or any other metal structure into which they come into contact with. Therefore, wherever one places a metallic temperature sensor (6) on a

coaxial derived applicator, current will flow in the metallic sensor because the sensor is perpendicular to the magnetic field.

In Figure 2, a diagrammatic cross-section of a circular waveguide (7) is shown where magnetic field lines (3) and the electric field lines (4) are illustrated for the transverse electric mode TE11. In this arrangement, the electric field is always perpendicular to the waveguide wall (8) and the magnetic field is always perpendicular to the electric field.

In Figure 3, a diagrammatic top view of field distributions along a circular waveguide (7) is shown were magnetic field loops (3) are separated by regions of high electric field (4). Note that the magnetic field loops are parallel to the sides of the waveguide wall (8).

In Figure 4, a diagrammatic side view of current flow in the walls of a circular waveguide (7) is shown. Here one can see that if a metallic sensor (6) is placed substantially parallel to the magnetic field at the side of the waveguide wall (8), then all current paths will cross the sensor and there will be no generated current flow in the sensor (6).

We have found that by placing the thermocouple sensor (6) substantially parallel to the magnetic field (3) at the wall of the waveguide (8), then substantially no current flows in the metallic elements of the sensor (6) and real-time temperature monitoring is possible without any substantial distortion.

The invention will now be further described by reference to Figure 5, which is a diagrammatic side elevation of a microwave applicator

including a temperature sensing thermocouple positioned in accordance with the present invention.

In Figure 5, a microwave applicator (11) has a circular waveguide (12) filled with a dielectric material (13). The waveguide (12) terminates short of the end of the applicator (11) providing an exposed portion (14) which forms a radiating antenna tip for the microwave energy. Towards the end of the applicator remote from the radiating tip (14), there is a coaxial feed cable (15) having an inner conductor (16) which directly excited the dielectric filled waveguide (12) via an in-line transition (17). The inner conductor (16) passes to the centre of the dielectric material (13) and a lateral conductor (18) which passes from the central conductor through the outer waveguide wall (12) forms a microwave break allowing the transition to cause the microwaves to launch into the dielectric material (13) as shown in Figures 1 to 3. The conductor (18) is insulated by insulation as it passes through the outer conductor formed by the waveguide wall (12).

The sensor positioned in accordance with the invention is a thermocouple (20) located on the outside of the radiating tip (14) for sensing the operating temperature. In accordance with the invention, the thermocouple (20) is positioned substantially parallel to the orientation of the magnetic field generated by the circular waveguide (12) when propagating microwaves, that is, along the line of the element (6) in Figures 2 and 4. Moreover, in order to avoid additional wiring, the thermocouple (20) is directly connected by a connection (23) to the outer conductor

waveguide wall at (21) and by a connection (24) to the lateral conductor (18) at (22). The connections (23,24) extend parallel to one another in a plane through the axis of the waveguide, and the one (23) terminates at (21) and the other (24) extends outside the wall (12) as far as the perpendicular plane through (22), and then runs round the circumference of the wall (12) to the conductor (18) at (22). Accordingly, the thermocouple signal passes out along the same coaxial cable bringing the microwave power to the radiating tip (14). Conventional circuitry (not shown) is used to sense and extract the DC signal.

The location of the thermocouple itself, at a position where there is no induced current in operation, enables real-time sensing of the operating temperature without any substantial distortion.

Although not shown, the applicator (11) is provided with a microwave-transparent protective coating of PTFE or other suitable material. The temperature sensor sensing thermocouple (20) is provided between the coating and the dielectric material as well as being insulated from the dielectric material.

CLAIMS

1. A microwave applicator (11) comprising a tubular waveguide (12) which, on transmission of microwaves, generates an electric field (4) orientated substantially perpendicular to the waveguide wall (12) and a magnetic field (3) substantially perpendicular to the electric field (4), and a sensor (20) including an elongate metallic element (20,23,24), said elongate metallic element being positioned on the waveguide (12) so as to be substantially parallel to the magnetic field (3) during microwave transmission, whereby substantially no induced current is generated in the metallic element (23,24) of the sensor which would otherwise cause distortion.

2. A microwave applicator as claimed in claim 1, in which the waveguide is filled with dielectric (13) which extends from one end so as to form an antenna (14) to emit microwave radiation, the sensor (20) being located in the side of the dielectric antenna.

3. A microwave applicator as claimed in claim 2, in which the elements (23,24) comprise connections which extend parallel to one another in a plane through the central axis of the waveguide and are connected, one (23) to the wall (25) of the waveguide (12), and the other (24) to a conductor (16) that powers the waveguide.

4. A microwave applicator as claimed in claim 3, in which the waveguide is powered by a coaxial cable (15) having a central conductor (16) which extends centrally into the dielectric (13) and to which the other connection (24) is connected.

5. A microwave applicator as claimed in claim 4, in which the central conductor (16) has a lateral conductor (18) that extends radially from it, and the other connection (24) is connected to the outer end of the conductor (18) at (22).

6. A microwave applicator as claimed in claim 5, in which the outer end of the conductor (18) extends through an aperture in the wall (25) of the waveguide (12) and is electrically insulated from it.

7. A microwave applicator as claimed in claim 5 or 6, in which the other connection (24) extends longitudinally of the waveguide from the sensor (20) and then circumferentially of the wall (25) of the waveguide (12) to the outer end of the conductor (18).

8. A microwave applicator as claimed in any one of the preceding claims adapted for medical use.

9. A method of positioning a sensor (20) including an elongate metallic element (23,24) on a microwave waveguide (12) comprising: selecting a tubular dielectric filled waveguide (12); determining the general orientation of the magnetic field (3) generated during microwave transmission; and positioning the elongate metallic element (23,24) substantially parallel to the orientation of the magnetic field (3).

10. A method as claimed in claim 9, in which the waveguide (12) is powered by a coaxial cable (15) and in which the output of the sensor (20) is connected to the coaxial cable (15).

11. A microwave applicator substantially as herein described with reference to the accompanying drawings.

12. A method of positioning a sensor substantially as herein described with reference to the accompanying drawings.

FIG. 1.

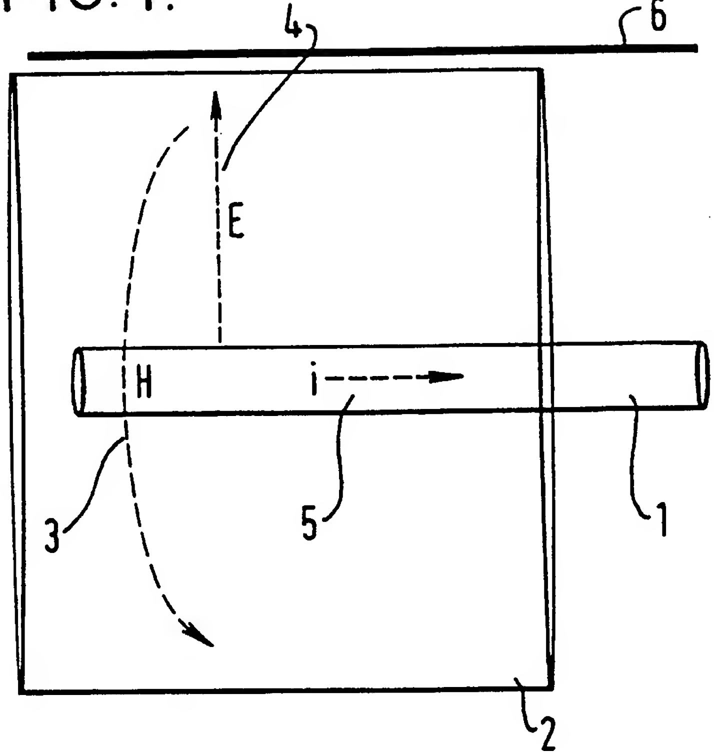


FIG. 2.

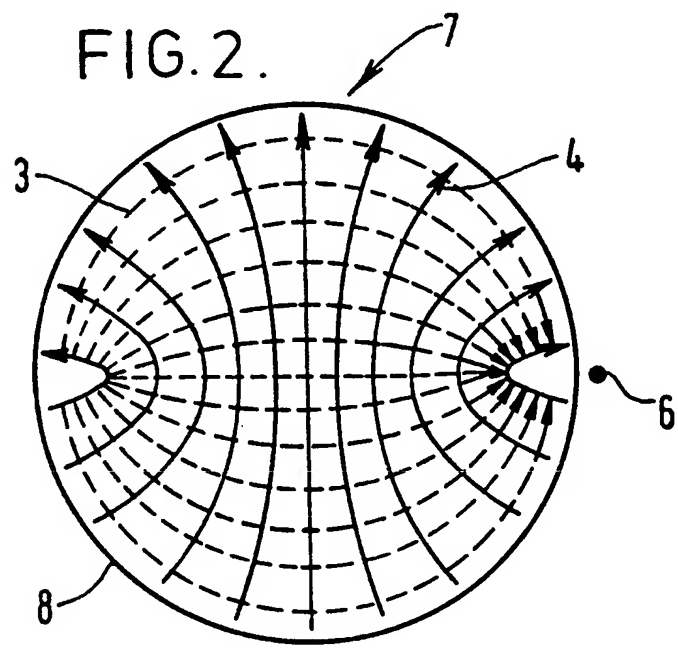


FIG. 3.

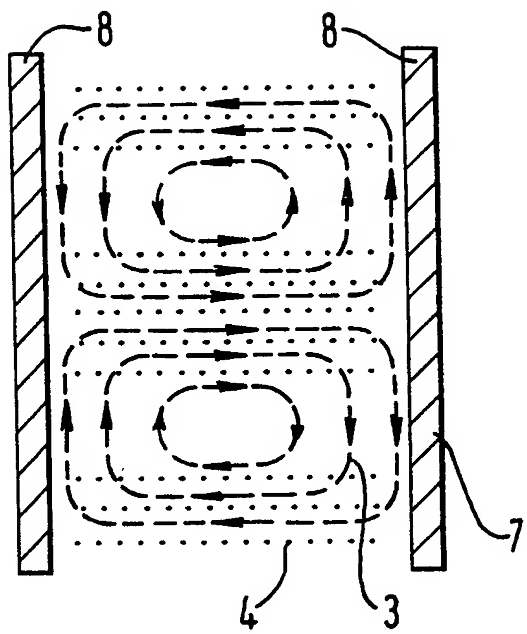


FIG. 4.

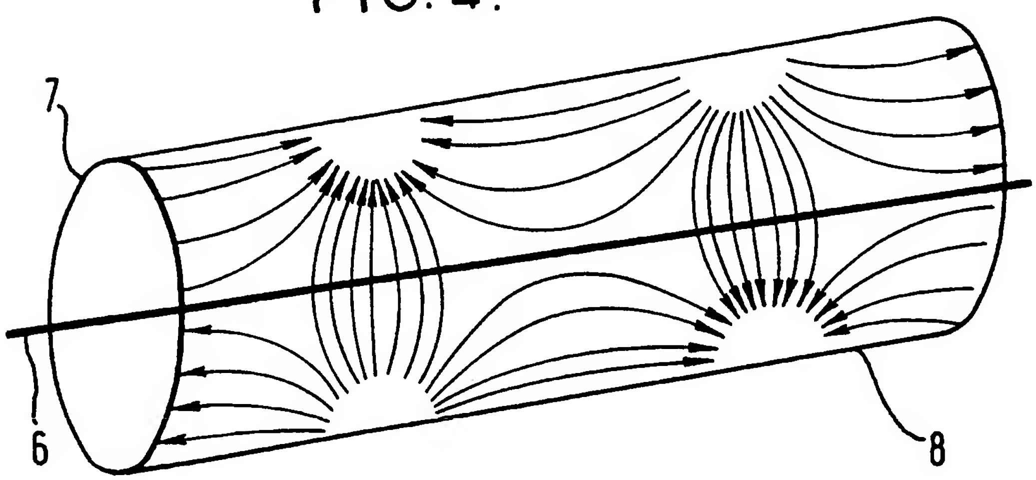
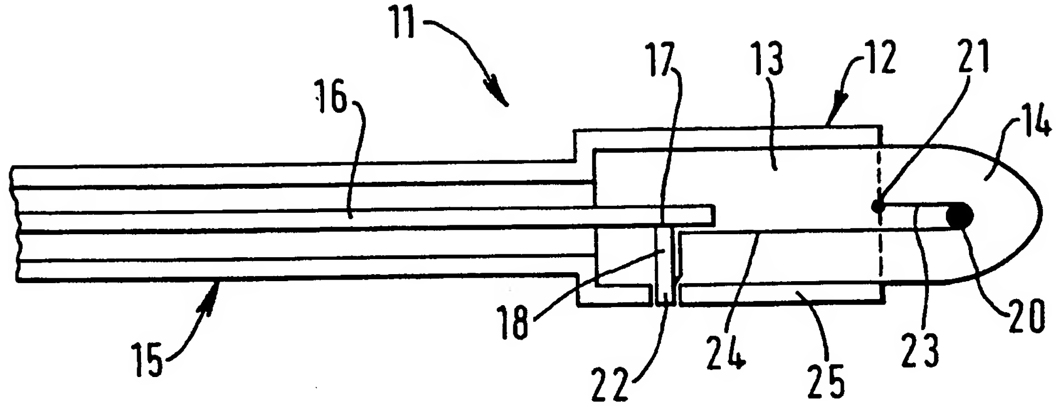


FIG. 5.



INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 99/01400

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61B17/36

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A61B A61N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 763 665 A (MASCUCH FRANK ET AL) 16 August 1988 (1988-08-16) column 2, line 3 - column 3, line 3	1,9
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A	WO 95 04385 A (CHEMRING LTD ;FELDBERG IAN (GB); CRONIN NIGEL (GB); EVANS MARTYN () 9 February 1995 (1995-02-09) column 5, line 18 - column 6, line 7 column 7, line 16 - line 21	1,9

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
26 August 1999	03/09/1999

Name and mailing address of the ISA	Authorized officer
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1

INTERNATIONAL SEARCH REPORT

International application No.

PCT/GB 99/01400

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 11,12
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box I.2

Claims Nos.: 11,12

Claims 11 and 12 contain a reference to the drawings, see PCT rule 6.2 a.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int tional Application No

PCT/GB 99/01400

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